INVESTIGATION OF CERAMIC ROOF, METALLIC ROOF AND CONCRETE ROOF THERMAL PERFORMANCE IN TROPICAL CLIMATE

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***ABSTRACT**. The objectives of this research are to investigate thermal performance of ceramic roof, metallic roof, and concrete roof. Experimental buildings were located in Universiti Teknology PETRONAS (UTP), Perak, Malaysia that had three different types of roof: ceramic roof, metallic roof, and concrete roof. This research measured temperature outdoor and indoor. The results of this research were the highest outdoor and indoor temperature compared between three types of roofs was on metallic roof. The highest heat flux compared between three types of roofs was on metallic roof. The highest value of cooling energy compared between three types of roofs was on metallic roof. The room in building with metallic roof needs more energy to reduce temperature than room in building with ceramic roof and concrete roof.*

***Keywords**: ceramic roof; metallic roof; concrete roof; thermal performance; heat flux; cooling energy.*

***ABSTRAK**. Tujuan dari penelitian ini adalah meneliti tentang suhu termal yang dihasilkan oleh atap genteng keramik, atap jenis logam, dan atap beton. Obyek untuk eksperimen dalam penelitian ini mengambil tiga bangunan dengan konstruksi atap berbeda (genteng keramik, logam, dan beton) yang berlokasi di Universiti Teknology PETRONAS. Penelitian ini menggunakan metode eksperimen dengan melakukan pengukuran suhu luar dan suhu dalam ruangan. Hasil penelitian ini menemukan bahwa atap jenis logam mempunyai suhu luar dan suhu dalam tertinggi, nilai heat flux tertinggi dibandingkan jenis atap genteng keramik dan atap beton, sehingga ruang dalam bangunan dengan jenis atap logam membutuhkan lebih banyak energi untuk menurunkan suhu ruangan dalam bangunan dibandingkan dengan atap jenis genteng keramik dan atap beton.*

***Kata kunci**: Atap genteng keramik, atap logam, atap beton, termal, heat flux, energi*

INTRODUCTION

Malaysia is hot and humid, the mean minimum temperature ranged from 22.8˚C to 25.4˚C. The mean maximum temperature ranged from 28.5°C to 32.4˚C. The highest temperature recorded was 35.3˚C. Average relative humidity throughout a day between 67% to 97% [1]. Campus of Universiti Teknology PETRONAS, Perak, Malaysia located at the latitude 4° 23' 11" N, longitude 100° 58' 47" E was considered as the study area about thermal performance.

The objective of this research is to investigate thermal performance of ceramic roof, metallic roof, and concrete roof.

METHODOLOGY

Description of Experimental Buildings

Experimental buildings were located in Universiti Teknology PETRONAS (UTP), Perak, Malaysia. They had three different types of roof: ceramic roof, metallic roof, and concrete roof. Figure 1 shows the experimental buildings with ceramic roof. Size of building with ceramic roof was 15m^2. There was a vent hole as air circulation.

Figure 1. Experimental building with ceramic roof
Source: Private documentation, 2011

On the other hand, figure 2 shows the experimental buildings with metallic roof. Size of building with metallic roof was 9m^2.

Figure 2. Experimental building with metallic roof
Source: Private documentation, 2011

And the last one is figure 3 which shows the experimental buildings with concrete roof. Size of building with concrete roof was 6m^2.

Figure 3. Experimental building with concrete roof
Source: Private documentation, 2011

Description of Equipment & Measurement

Thermal monitoring system was equipped with digital thermometer which measured temperature outdoor and indoor every one hour. Outdoor measurement will point on the roof and wall surface, while indoor measurement will point on the ceiling and the wall surface. The measuring period was 8-21 December 2011.

Heat Flux and Thermal Energy Equations

The following equation is used to represent conductive heat flux: [2]

$$q_{cond} = K\frac{(T_1 - T_2)}{L} \quad (1)$$

The conductive heat flux through the roof is represented by q_{cond}. T_1 and T_2 represent outdoor and indoor temperature. Thermal conductivity is represented by K. Thickness of roof is represented by L.

Tabel 1. Thermal Conductivity (K) [3]

	Ceramic, clay	Metal, Zinc	Concrete, stone
Thermal conductivity (K) ($Wm^{-1}K^{-1}$)	0.15 – 1.8	116	1.7

The other equation to calculate thermal energy is as follow:

$$E_t = m \cdot C \cdot \Delta T \quad (2)$$

Thermal energy (cooling energy) in this research is used to reduce indoor temperature to achieve indoor thermal comfort. E_t is thermal energy, m is mass, C is heat capacity, heat capacity of air is 1.012 $Jg^{-1}K^{-1}$ [4], and ΔT is temperature change (indoor temperature to comfort temperature).

RESULTS AND DISCUSSION

The first analysis will compared outdoor and indoor temperature of each buildings with different types of roofs. Figure 4 shows temperature variations outdoor and indoor of building with ceramic roof on clear day. The highest outdoor temperature was 47.2°C at 13:00 and the lowest outdoor temperature was 28.9°C at 17:00. The highest indoor temperature was 35.7°C at 15:00 and the lowest indoor temperature was 28.4°C at 10:00.

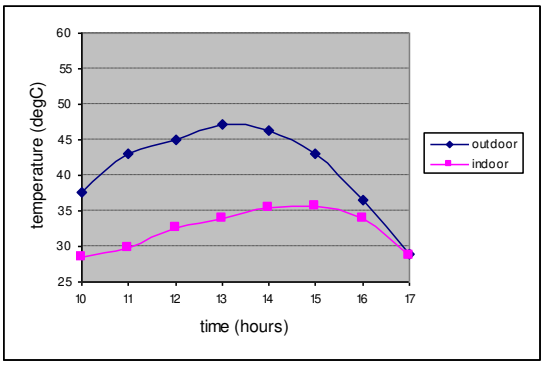

Figure 4. Temperature of building with ceramic roof
Source: Analysis result, 2011

Next figure 5 shows temperature variations outdoor and indoor of building with metallic roof on clear day. The highest outdoor temperature was 55.5°C at 12:00 and the lowest outdoor temperature was 28.2°C at 17:00. The highest indoor temperature was

51.4°C at 13:00 and the lowest indoor temperature was 28.1°C at 17:00.

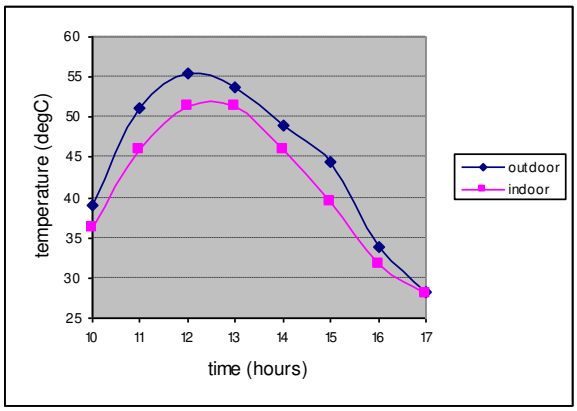

Figure 5. Temperature of building with metallic roof
Source: Analysis result, 2011

On the other hand, figure 6 shows temperature variations outdoor and indoor of building with concrete roof on clear day. The highest outdoor temperature was 41°C at 14:00 and the lowest outdoor temperature was 30.1°C at 10:00. The highest indoor temperature was 32.5°C at 16:00 and the lowest indoor temperature was 25.8°C at 10:00.

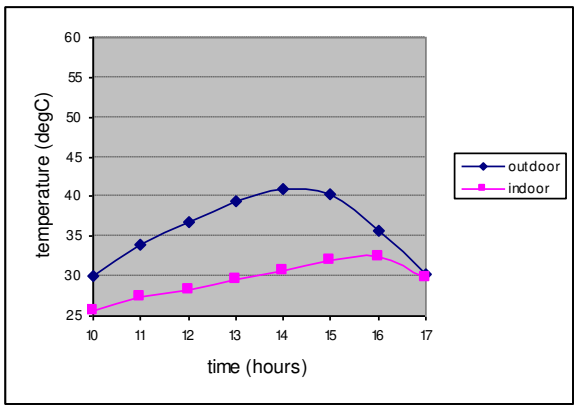

Figure 6. Temperature of building with concrete roof
Source: Analysis result, 2011

The highest outdoor temperature between three types of roofs was 55.5°C at 12:00 on metallic roof. The highest indoor temperature between three types of roofs was 51.4°C at 13:00 on metallic roof. The outdoor and indoor mean temperature of ceramic roof higher than concrete roof.

The second analysis compared heat flux each roof type is shown in figure 7. The highest heat flux was 4635 W/mK at 11:00 and 15:00 on metallic roof. At this time, metallic roof presented high values of heat gain. The lowest heat flux was 9.775 W/mK at 17:00 on concrete roof. At this time, concrete roof presented low values of heat gain.

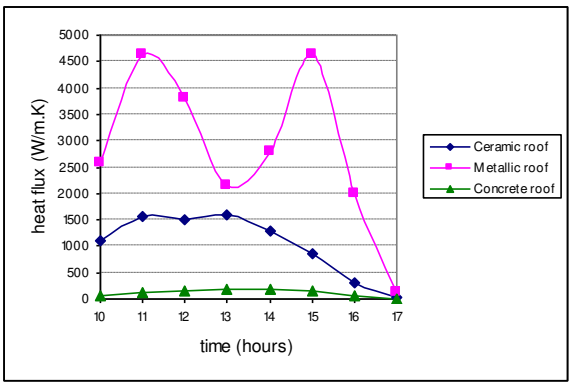

Figure 7. Heat flux comparison with various roofs
Source: Analysis result, 2011

The third analysis compared thermal energy each type of roof to reduce indoor temperature to achieve indoor thermal comfort. Thermal Comfort Zone stipulated by ASHRAE Standard 55 [5]. Human can feel comfortable in this condition. Thermal comfort for 60% to 90% relative humidity is temperature range of 20ºC to 26ºC [6]. Thermal comfort of this research was assumed 23ºC to calculate thermal energy (cooling energy) need to reduce indoor temperature. Figure 8 shows cooling energy need to reduce indoor temperature on each type of roof.

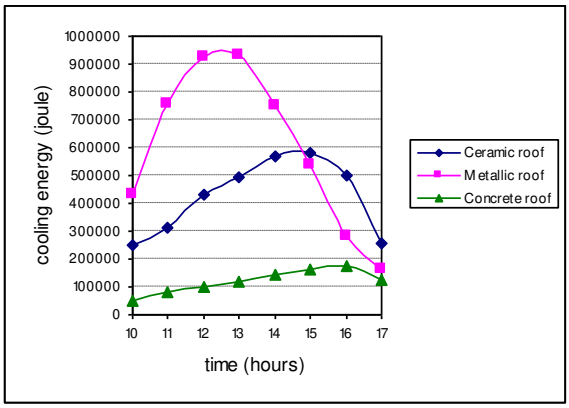

Figure 8. Cooling energy need to reduce indoor temperature with various roofs
Source: Analysis result, 2011

The highest value of cooling energy was 932021.6 Joule at 12:00 on metallic roof. The lowest value of cooling energy was 50094

Joule at 10:00 on concrete roof. The room in building with metallic roof needs more energy to reduce temperature than room in building with ceramic roof. The room in building with ceramic roof needs more energy to reduce temperature than room in building with concrete roof.

CONCLUSION

The highest outdoor temperature compared between three types of roofs was on metallic roof. The highest indoor temperature compared between three types of roofs was on metallic roof. The outdoor and indoor mean temperature of ceramic roof higher than concrete roof.

The highest heat flux compared between three types of roofs was on metallic roof, so metallic roof presented high values of heat gain. The lowest heat flux compared between three types of roofs was on concrete roof, so concrete roof presented low values of heat gain.

The highest value of cooling energy compared between three types of roofs was on metallic roof. The lowest value of cooling energy compared between three types of roofs was on concrete roof. The room in building with metallic roof needs more energy to reduce temperature than room in building with ceramic roof. The room in building with ceramic roof needs more energy to reduce temperature than room in building with concrete roof.

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